GOLF SWING ANALYSIS APPARATUS AND METHOD

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Field of the Invention

This invention relates to aids for golfers to improve their play, and, more particularly, relates to devices and methods for analyzing a golfer's swing.

Background of the Invention

It is known that the ability to strike a golf ball correctly is important to a golfer's continued enjoyment of and improvement in the game. Thus, most golfers expend considerable effort to refine and perfect their golf swing. In the last few years, golf has moved from a somewhat elite sport to one with a more general public appeal. Despite the greater appeal, it has been noted that golfers as a group are not significantly improving. It is apparent that correcting defects of swing is difficult, even if one has access to a "pro" to assist in the process.

One problem in developing a good golf swing is the fact that there is a discontinuity between muscle memory and visual cues. Furthermore, since a golf club head moves so quickly through a golfer's line of sight, it is difficult to judge the characteristics of the flight of the club head at impact. Golfers are thus resigned to

looking at second order effects (golf ball travel, mechanics of swing and the like) to provide information on swing defects. Flaws in the swing are typically corrected by addressing deficiencies in these same second order effects and are validated only by the flight of the ball, itself a second order effect. If a golfer were able to see first order effects during a golf swing (club face angle, club head path, club face impact point, and club head velocity, both absolute and relative) a golfer could more quickly realize immediate results in a change in swing, and thus teach muscle memory more efficiently.

Devices that are attached to a golf club have been heretofore suggested for tracking a golf swing (see U.S. Patent Numbers 5,288,080, 6,139,442, 5,692,964, 3,753,564, 5,839,969, 5,230,512, 5,676,603, 5,441,269, and 5,792,001, for example). Heretofore known devices have not, however, proven to be effective for visualization by a user of much more than the path of club head travel, have not provided a golf swing display that provides a user with intuitive swing correction information, have not provided timely feedback, and/or have required specialized clubs or club adaptation. Improvement in such devices and methods could thus be

utilized and would prove useful to the growing population of golfers.

Summary of the Invention

This invention provides apparatus and methods for aiding a golfer in golf swing improvement by allowing the golfer to analyze his or her swing immediately before and after ball impact during actual golf club use. Real time feedback to the player is provided by accommodating observability of club face angle, club head path, club face impact point, and club head velocity, both absolute and relative, during a stoke. The apparatus displays the stroke in such a way that a user is provided with intuitive swing correction information.

The apparatus of this invention may be integrated into a golf club or attached to any of a user's existing clubs. The apparatus includes first and second spaced display elements that are positioned so that they appear to a user of the club similarly located relative to the golf club head face. Each provides a light emanation (active or passive) during a golf stroke that is or appears to be consistent. A light emitting display is positioned between the first and second elements and is elongated in appearance (a plurality of light emitting elements is preferred).

A control unit is operatively associated with the light emitting display (either locally or remotely) for activating and deactivating the display thereby providing several short intervals of light emission during the golf stroke. The control unit preferably has associated therewith means for variation of activated/deactivated interval period and/or frequency. Structure is provided for associating the elements and/or display with the golf club so that the display appears to a user during club use at a position along the club head face.

The method for aiding a golfer in golf swing analysis and improvement of this invention includes providing apparently consistent light emanations during a golf stroke from first and second spaced positions that are similarly located relative to an associated golf club head face. Several short intervals of light emission are provided from a location between the first and second positions during the golf stroke. A persistence display perceptible by a user of the golf club is thus established having a ladder-like configuration that varies in appearance responsive to the user's golf swing.

The apparatus and methods of this invention provide feedback to the user in performance, train the user for improved muscle memory, and help to build specific user

muscles. The apparatus functions with the eye persistence of a user to provide a persistence display during a stroke that intuitively illustrates defects in a user's swing, particularly those related to golf club head face angle and path, ball impact point, and head velocity. Correction is suggested by variations in the appearance of the persistence display.

In a further embodiment of the device, the apparatus can be used to trigger an electrical stimulation of a user's muscles at proper times to build muscles specific to the sport and/or to cue swing correction.

It is therefore an object of this invention to provide improved apparatus and methods for golf swing analysis and particularly at club head/ball impact.

It is another object of this invention to provide apparatus and methods providing golf swing analysis to the user during actual club use.

It is still another object of this invention to provide an apparatus for aiding a golfer in golf swing improvement that is integrated with or attachable to a golf club.

It is yet another object of this invention to provide apparatus and methods for aiding a golfer in golf swing analysis that provides effectively for observation

by a user of a plurality of swing components and that provides a user with timely and intuitive swing correction information.

It is still another object of this invention to provide apparatus and methods for aiding a golfer in golf swing improvement by accommodating observability of club face angle, club head path, club face/ball impact point, and club head velocity, both absolute and relative, by a user during a golf stroke.

It is yet another object of this invention to provide apparatus and methods for aiding a golfer in golf swing improvement wherein a persistence display established during a stroke intuitively illustrates defects in a user's swing, correction being suggested by variations in the appearance of the persistence display.

It is another object of this invention to provide an apparatus integrated with or attachable to a golf club for aiding a golfer in golf swing improvement that includes first and second spaced display elements positioned so that each appears similarly located relative to an associated golf club head face and with each providing at least an apparently consistent light emanation during a golf stroke, an elongated light emitting display positioned between the first and second

spaced display elements, and a control unit operatively associated with the elongated light emitting display for activating and deactivating the elongated light emitting display to provide several short intervals of light emission from the elongated light emitting display during the golf stroke.

It is still another object of this invention to provide an apparatus integrated with or attachable to a golf club for aiding a golfer in golf swing improvement that includes a plurality of light emitting elements, a controller operatively associated with the plurality of light emitting elements for activating and deactivating the plurality of light emitting elements to provide several short activated intervals from the plurality of light emitting elements during a golf stroke, the controller having selection means associated therewith for variation of activated/deactivated interval frequency of the plurality of light emitting elements during the golf stroke, and structure for associating at least the plurality of light emitting elements with the golf club so that the plurality of light emitting elements appear to a user at a position along the associated golf club head face.

It is yet another object of this invention to provide a method for aiding a golfer in golf swing analysis and improvement that includes the steps of providing at least apparently consistent light emanations during a golf stroke from first and second spaced positions similarly located relative to an associated golf club head face, and providing several short intervals of light emission from a location between the first and second positions during the golf stroke.

With these and other objects in view, which will become apparent to one skilled in the art as the description proceeds, this invention resides in the novel construction, combination, and arrangement of parts and method substantially as hereinafter described, and more particularly defined by the appended claims, it being understood that changes in the precise embodiment of the herein disclosed invention are meant to be included as come within the scope of the claims.

Brief Description of the Drawings

The accompanying drawings illustrate a complete embodiment of the invention according to the best mode so far devised for the practical application of the principles thereof, and in which:

FIGURE 1 is a perspective view showing a portion of a golf club with an apparatus of this invention mounted on the shaft thereof above the head;

FIGURE 2 is a partial top view of the apparatus as shown in FIGURE 1;

FIGURE 3 is a mechanical assembly diagram of the printed circuit board of the apparatus of FIGURE 1;

FIGURE 4 is a diagram illustrating the persistence display established in operation of the apparatus of FIGURE 1;

FIGURE 5 is a block diagram of one embodiment of the apparatus of this invention;

FIGURE 6 is a block diagram of a second embodiment of the apparatus of this invention;

FIGURE 7 is a waveform diagram illustrating timing of display intervals repeated during a stroke by the apparatus;

FIGURE 8 is a schematic diagram of one embodiment of a velocity switch applicable in the apparatus illustrated in FIGURE 6;

FIGURES 9A, 9B and 10 through 13 are flow diagrams illustrating software control of operation of the apparatus of this invention;

FIGURES 14, 15A, 15B, 16A and 16B are diagrammatic illustrations showing the intuitive persistence display observed for various strokes;

FIGURES 17 and 18A through 18E diagrammatically illustrate a third embodiment of the apparatus of this invention; and

FIGURE 19 is a block diagram of yet another embodiment of the apparatus of this invention.

Description of the Invention

An embodiment 31 of the apparatus of this invention attachable to shaft 32 of any golf club 33 is illustrated in FIGURES 1 and 2. It should be appreciated that other club attachment points and configurations could be conceived, and that the apparatus of this invention could as well be integrated into a specially manufactured golf club or clubs having structure adapted thereto.

The apparatus and methods of this invention use a phenomena called visual eye persistence to establish a persistence display for real time feedback related to defects in a golfer's swing, or stroke. Visual eye persistence is a known physiologic process whereby the human brain visualizes the path of a fast moving light source as a streak of light in the observer's field of vision (similar to seeing a "shooting star" at night).

Utilizing the apparatus of this invention to establish such a persistence display, a golfer receives immediate feedback on the mechanics of his/her swing allowing correction of any defects accordingly. Muscle memory is trained much faster when combined with such feedback, thereby providing more immediate and lasting results.

The apparatus achieves the persistence display by placing a row 35 of illuminating elements 37 (such as light emitting diodes (LED's), low power lamps, fiber-optic elements, LCD's, fluorescent or reflective elements, combinations thereof, or the like) in the viewer's line of sight. Elements 37 preferably form a linear display 38 that is substantially parallel relative to golf club face 39 at club head 41 when viewed as shown in FIGURES 2 and 3. However, a perfectly parallel (to the club face) linear arrangement of elements 37 is not always required and may under some circumstances (such as use by golfers having a predictable swing defect or handicap not likely to be remedied) not be desired, in which case deviations from a perfectly linear arrangement of elements 37 may be utilized as will become apparent as the description proceeds.

Preferably, apparatus 31 includes a housing 45 affixed to a club clamp 47 for attachment of apparatus 31

to shaft 32 of club 33. A variety of club shaft spacers/shock absorbers 49 (see FIGURE 2), preferably made of a polymeric material such as urethane, are provided to accommodate firm attachment of apparatus 31 to club shafts of various diameters while providing apparatus 31 circuitry shock absorption during use of the associated club. Housing 45 is affixed to clamp 47 at pivot 51 so that row 35 of elements 37 can be rotated relative to a viewer and, in combination with clamp 47, adjusted to extend parallel to and a selected distance above golf club head 41.

As shown in FIGURE 3, a mechanical assembly 53 (a printed circuit board, for example) anchors and interrelates the apparatus electronics 55, battery 57, and display 38 (at the longer portion 59 of assembly 53). Portion 59 is of a length sufficient so that the row of equally spaced elements is accommodated and is about the length of a club face 39.

In the preferred embodiment of row 35 of elements 37, the two outside display elements 63 and 65 are established so that light is at least apparently consistently emanating therefrom during a golf stroke (i.e., either constantly emanating light or strobing at such a rapid pace that either a constant streak or very

closely spaced light pulses are experienced by the user regardless of club head speed during the observed stroke). While as shown herein elements 63 and 65 are active elements (LED's preferably, or lamps and the like), passive elements (LCD's, reflective, fluorescent, passive fiber optic elements, or the like) may also be utilized for these outside light emanation sources.

Elongated light emitting display 67 of row 35 is positioned between elements 63 and 65, and is preferably established by a plurality of light emitting elements 69 (preferably LED'S), though a single light emitting bar lamp or active fiber optic arrangement could be utilized (see FIGURE 19). Inner display 67 of the apparatus can consist of one to N elements 69 connected in either series or parallel and switched on and off at or near the same time as discussed below.

Elements 69 are rapidly activated and deactivated multiple times during a single stroke (i.e., strobed very quickly) so that several short intervals of light emission from display 67 are experienced in a persistence display by a user of the apparatus. The combined operation of display 67 and elements 63 and 65 during a stroke establishes the persistence display, which has a ladder-like configuration as illustrated in FIGURE 4 (and

discussed in greater detail with reference to FIGURES 14 through 16).

Since the outer elements 63 and 65 apparently consistently emanate light during the entire golf swing, and since they are similarly located relative to golf club face 39 in use (i.e., arranged so that a line through both would be parallel to face 39), they will appear to the user as streaks or consistent dotted rows of light (or rails) 75 positioned apart by about the length (heel to toe) of golf club head 41 (about 3 to 5 inches depending on embodiment and club). Because elongated display 67 is cycled on and off (as hereinafter discussed) at a selected rate, the short intervals of light emission appear as bars of light (or rungs) 77 extending between rows of light 75 during the stroke. The faster the golf club head moves during the stroke, the further apart will be rungs 77 (where the selected interval rate remains constant).

When the club is swung incorrectly or there is a defect in the swing, the persistence display perceived by the user will be distorted in a way that intuitively tells the golfer what is wrong (see FIGURES 14 through 16). Club head velocity, and changes therein from one stroke to the next, is apparent, allowing a golfer

utilizing the apparatus to select a desired tempo. Deviations from that tempo will be obvious in the displayed image and can thus be compensated for.

The apparatus is constructed to be quite light weight, and use of the apparatus does not require the golfer to do anything out of the ordinary when swinging the club. In fact, if the golfer's head moves too much, or the golfer does not focus on ball 79, the persistence display will not be effectively visible since such displays rely on passage of the light source through the field of vision (i.e., not being directly watched by the observer) to be most effective. In order to create a non-distorted image, velocity (speed and direction) of the display element group must remain as constant as possible through a significant portion of the entire field of view. Some velocity inconsistency can be controlled by the arrangement (linearity or divergence therefrom) of the display element group where the inconsistency is predictable.

Operational controls for apparatus 31, as shown in a first, simplified, embodiment in FIGURE 5, include microprocessor 81 with embedded software, microprocessor 81 powered by battery 83. Microprocessor 81 controls operation of amplifier/drivers 85 and 87 providing power

to outside elements 63/65 and inside elongated display/elements 67/69, respectively, of display 38. User programmability is provided at input 89 for selection of at least the activated/deactivated interval period (of activation) and frequency of display/elements 67/69, to thereby accommodate golf strokes involving different club head speeds (from putting to driving). Input 89 may be any known device from quite simple dial or push button inputs to devices of greater complexity (including personal computers).

While the apparatus heretofore illustrated shows all elements of the electronics housed locally, remote location of some of the electronics (away from the club head for example, or even removed from the club altogether) may be desired as can be accommodated utilizing known techniques.

FIGURE 6 shows another embodiment of the operational controls for an apparatus of this invention that includes additional features (some or all of which may be employed in any given implementation). Velocity switch 91 is provided to automatically turn on the electronics to display 38 when the golf club is being swung. One shot 93 (either a separate electronic circuit or embedded software in microprocessor 81) controls the period of

time (such as 2 or 3 seconds) that the electronics remain active, thereafter turning them back off to preserve battery power.

Accelerometer 95, such as a micro-electromechanical system (MEMS) device, may be incorporated to provide X, Y and Z axis acceleration, direction, angle, and force of ball hit data from the golf swing to microprocessor 81. This data can be either downloaded from microprocessor 81 memory at a later time or transmitted and displayed using standard known techniques for real time (or archival) analysis of the golf swing.

Light intensity sensor 97 (a photo diode, for example) may be included so that adjustment of intensity of the various elements of display 38 can be automatically accommodated to compensate for various ambient light conditions. As an alternative to, or in addition to, input 89, ladder speed control 99 (either embedded programming at microprocessor 81 or a separate unit) can be utilized in conjunction with accelerometer 95 to determine the distance between rungs 77 of the persistence display by automated variation at microprocessor 81 of the activated/deactivated interval period and frequency of display/elements 67/69 for various accelerometer 95 sensed club head speeds.

TENS trigger 101 option can be provided with accelerometer 95 to turn on an external TENS (transcuetaneous electrical nerve stimulator) device mounted to a user that would stimulate the proper arm muscles at the right time to thereby cause impact with the golf ball with increased force and/or cue the golfer regarding corrected swing events.

For the purposes of practice, trigger 101 can be used to trigger a TENS type device to fire and provide increased muscle power at the exact moment that the golfer strikes the ball. Repeated practice will cause improvement in muscle tone specific to those muscles required for hitting the golf ball, and will aid in muscle memory in the spinal cord.

The central nervous system uses the optic sensory receptors to monitor changes, processes and interprets the optic sensory receptors, makes a decision on what action needs to be done at that moment, and effects a response by activating muscles. These responses are based on past experiences, body reflexes, and current circumstances.

The peripheral nervous system is outside of the central nervous system, and is a communication path that links the entire body to the central nervous system, and

consists of spinal nerves that extend to and from spinal cord, and cranial nerves that carry impulses to and from the brain. These in turn operate the motor or efferent neurons to effect muscles through the voluntary or somatic nervous system or the autonomic nervous system that effect involuntary muscle responses.

Neurons communicate with other neurons through the release of neurotransmitter chemicals activated by electrical stimulus. An external transcuetaneous electrical nerve stimulator, can be used to externally activate neurons at various locations of the body. Communications between neurons are accomplished by action potentials that change the resting potential of the nerve from its quiescent state to a change of about 100mV in a time of about 3 milliseconds due to rapid sodium potassium ion permeability. This depolarization followed by re-polarization is followed by an absolute refractory period of about 1 millisecond where the nerve will not respond to another stimulus. Therefore, an external electrical signal generated at the time of the absolute refractory period can be used change the resting potential to cause a group of muscles to contract at a chosen time. Since the action potential is a constant voltage, the intensity of external stimulation makes no

difference to the nerve. It is only the frequency of stimulation that the central nervous system is coded.

Skeletal muscles are the longest muscle cells, produce body heat, exert tremendous power, can be controlled voluntarily, and may also be activated involuntarily by electrical stimulation. Muscles respond to stimulus from internal mechanisms such as the 5 senses, and external stimulation such as electrical or chemical means. They contract, stretch, and are elastic in order to resume resting length after contraction or extension.

It is well known that an electrical stimulation of a muscle group will cause involuntary movement of that muscle, with electrodes attached at the proper location, and the proper electrical signal. A single electrical stimulus will causes muscle contraction for about 30 milliseconds and then the muscle requires a period of relaxation of about 100 milliseconds. If multiple voltage stimulus is applied to a muscle at an increasingly faster rate, the relaxation between twitches becomes shorter and shorter, and a sustained contraction called tetanus occurs. The volley of impulses in rapid succession will increase the muscle power at the time of stimulation.

For golfers, application of TENS electrodes at specific locations, such as both arms or legs, can be used to apply a volley of impulse and prolonged tetanus at a specific time triggered by microprocessor 81 through trigger 101 responsive to input data from accelerometer 95, thereby inducing enhanced muscle performance at the time of stimulation.

The brain utilizes fact memory to learn explicit information such as names, faces, poems, dates, and the like. Skill memory is concerned with less conscience learning, involves motor activity of the muscles, and is best learned by repeated activity (such as hitting a golf ball). The apparatus of this invention involves the visual receptors of the eye in sensing and encoding patterns of light from display 38, and the brain provides meaning to these patterns. The brain then transmits information to the somatic reflexes mediated by the spinal cord and alters previously learned reflexes. Repetition of perfect practice, moderated by the apparatus of this invention, then changes the old bad reflexes previously stored as muscle memory. The TENS option can also work to reinforce these changes by delivering stimulus cues to the golfer regarding his or her swing characteristics.

Transmitter 103 may be provided to remotely display or report data stored at microprocessor 81 memory (for example, data provided from accelerometer 95 or use history data).

FIGURE 7 illustrates the waveforms from microprocessor 81 and drivers 85/87 into display 38. The inside display/elements 67/69, are turned on for an interval period T1 at an interval frequency T2. For example, using programming input control, period T1 may be set at about 200 microseconds (as low as 50 microseconds) at an interval frequency T2 of about every 7 milliseconds (down to as little as about 4 milliseconds) for use with a golf club driver. Period T1 may be adjusted, however, to be about 1.5 milliseconds (up to about 3 milliseconds) at 15 millisecond T2 intervals (up to about 35 milliseconds) for use with a putter. Outside elements 63/65 are turned on and remain on throughout the golf swing (T3). In general the minimum activated/deactivated interval frequency ratio useful would be about 1/2, user variability of the activated/deactivated interval frequency ratio in a range between about 1/2 to at least about 1/35 being preferred. Overall, it is preferable that light bursts at inside display elements 67/69 be of short enough duration to

apparently "stop" motion of display 38 (and thus the club head) at each burst.

Figure 8 shows one embodiment of velocity switch 91. Switch 91 includes thin metal levers 105 and 107 with electrical contacts 109 opposingly positioned at each. Weight 111 is attached to lever 107. When the club head is swung as indicated by arrow H, weight 111 is set in motion as indicated at arrow W and electrical contact at contacts 109 is established thereby, thus closing the circuit and activating the apparatus electronics. When club head motion ceases, electrical contact is broken by settling of weight 111, thus opening the circuit and deactivating apparatus electronics. Other devices could be utilized (other sorts of accelerometers for example) to perform the velocity switch function.

Turning now to FIGURES 9A, 9B and 10 through 13, program control is illustrated. As shown in FIGURE 9A, the basic apparatus as illustrated in FIGURE 5 will only generate the ladder-like persistence display pattern. Rung 77 spacing is controlled by a user feedback element as discussed above. Main program flow simply queries the user input device and sets the interrupt interval based on input. This allows a user to speed up or slow down the interval between rungs 77, allowing adjustment

between clubs. The interrupt routine (FIGURE 9B) is executed periodically based on the interrupt interval set in the main program loop. It's only job is to determine if the next display interval is due to be a rung 77 (all display 67 on) or a rail 75 (only outside display elements 63/65 on).

Where the apparatus of this invention includes switch 91, program control responds to generate a signal when a swing is started, actuate the persistence display pattern for a period of time long enough to allow the golfer to see it, and then deactivate the electronics and thus cease the persistence display pattern (FIGURE 10). Including those heretofore shown, there is a potential for 4 user inputs: rung 77 interval period and frequency setting; display hold-off setting (the amount of delay after receiving the external trigger before the display pattern begins); display duration setting (the amount of time the display pattern is active); and, for some switch 91 embodiments, trigger sensitivity setting (the amount of force - acceleration - required to constitute a trigger event). The interrupt routine is identical to the routine described in the previous section.

With the addition of accelerometer 95, characteristics of multiple swings can be stored for

later retrieval and review. This will require another interrupt routine that simply reads values from the accelerometer and stores them into a data memory of microprocessor 81. It is more desirable to add storage to a triggered algorithm. In a non-triggered scenario, oldest data would be lost first. Here, the data is sampled on a periodic basis that is not user adjustable. In this way, appropriate DSP algorithms can be applied to the data to filter out unwanted characteristics or to apply compression for maximum memory utilization (FIGURE 11). For example, it would be desirable to filter out all activity that is not swing related.

When utilizing trigger 101 with a TENS unit adapted for the apparatus of this invention, by analyzing accelerometer 95 data in real time it is possible to determine when the club should strike the ball based on previous consistent data (FIGURE 12). This event can be communicated back to the golfer by providing transcuetaneous electrical nerve stimulation feedback to stimulate a muscle group. This feedback can be provided or used to either enhance muscle performance during this time or to provide a simple feedback signal that creates a gentle "twitch" in a muscle group providing an indication of the event (ball striking in this case,

though other events could be sensed and cued with appropriate analysis and programming). The trigger event can be detected in an interrupt routine very similar to the storage interrupt routine. The DSP is now used to detect the contact point based on previous data as well as signal conditioning for storage.

Wireless data transmission, when desired, can be accomplished in any number of ways. First, the transmission link can be RF, Infrared, Magnetic, optical, or any other means. Triggering of the data transfer can be triggered manually or after each swing. One possible program scenario is illustrated in FIGURE 13. In this case, the user input for data transfer could be an external switch, or, alternatively, could be triggered by the DSP element in the accelerometer interrupt routine.

It could be desirable to capture the ladder pattern using an external video camera with a slow shutter speed. This will allow the entire pattern of the swing to be viewed and analyzed at a later time. While this function will not help improve the muscle-memory training process, it could be useful in analyzing and correcting trend-related problems with the swing. Accelerometer 95 data could be displayed rather than, or in addition to, the

ladder pattern, which could then be captured on the video to provide further data to an instructor or student.

FIGURES 14 through 16 provide diagrams illustrative of the rail light patterns 75 and rung light patterns 77 perceived in the persistence display by a right handed user of the apparatus of this invention (golf ball 79 is a real item that the eye sees in addition to the optical display). Perceived rungs 77 of the ladder-like persistence display will indicate the orientation of the club face at each position. Unlike systems that indicate club face position at only a single point in the swing, rungs 77 will show a dynamic picture of the club face orientation before and after ball impact.

Perceived rails 75 of the persistence display indicate club head path through the impact point on the golf ball. The rails will also provides the user with feedback on where the ball hits the club face (from heel to toe). Keeping the ball impact point centered between rails 75 increases chances of hitting the club's "sweet spot".

In order for a golfer to see the image, he or she must concentrate on the ball. Persistence of vision is an involuntary process. Trying to see the image will actually make the image more difficult to see. Thus, the

user must keep his or her head still through the entire stroke (note that the fact that a user has not seen clearly the persistence display is itself an indication of a correctable fault in the user's swing).

FIGURE 14 illustrates the pattern of the persistence display when the ball is correctly addressed (i.e., a square hit ball with the club face perpendicular to the golf ball). This pattern is observed when the golf club head travels straight through the ball and the club face is square (the ball traveling in a path in the same direction as the club head at impact).

FIGURE 15A illustrates the pattern of the persistence display when the ball is hooked. The path of the club travels from the inside out (for a right handed golfer), but the club face is square at impact, the ball will travel in a path perpendicular to the club face. But, because of friction, a slight counter-clockwise spin will be imparted to the ball, causing it to gently hook. This type of flaw is not as severe as a closed club face (FIGURE 15B). When the face of the club travels straight through the ball, but the club face is closed at impact, the ball will have a severe counter-clockwise spin causing it to hook more severely. Friction can also cause the ball to be pushed off of the club head path,

causing the ball to start left. This swing flaw is much more severe than an inside-out flaw.

FIGURE 16A illustrates the pattern of the persistence display when the ball is sliced. Here the path of the club travels from the outside in (for a right handed golfer), but the club face is square at impact. The ball will travel in a path perpendicular to the club face. Because of friction, a slight clockwise spin will be imparted to the ball, causing it to gently slice. This type of flaw is not as severe as an open club face (FIGURE 16B). When the face of the club travels straight through the ball, but the club face is open at impact, the ball will have a severe clockwise spin causing it to slice more severely. Friction can also cause the ball to be pushed off of the club head path, causing the ball to start right. This swing flaw is more severe than an outside-in flaw.

As can be seen, the persistence display provides intuitive feedback of most major types of swing flaw, leading to ready correction in practice. The display will actually show the user the location and orientation of the golf club head at the point of ball impact, the direction of travel of the head relative to his or her

body and the desired direction of golf ball flight, and provide an indication of club head velocity.

Another embodiment 115 of the apparatus of this invention is diagrammatically illustrated by FIGURES 17 and 18A through 18E. These figures illustrate only the spatial relationship of the parts of display element group 117 of this embodiment that are observable by a user as a persistence display, the apparatus being otherwise substantially identical (or including redundant identical elements as would be obvious) in terms of electronics and operation as heretofore described. As shown in FIGURE 17, first row of elements 119 is substantially the same as heretofore described including outer elements 63 and 65 and inner display/elements 67/69. A second row 121 of light emitting display elements 123 (plural LED's, for example) is spaced from and substantially parallel to the element of first row 119. Operated as described hereinafter, this apparatus can display deviations from a desired absolute velocity of the display element group 117 (and thus the golf club head). Rotation of the display element group can also be shown.

If display element group 117 moves from right to left with the golf club, left row 121 would be the

leading row and right row 119 the trailing row. The distance between the two rows is designated "ds". Leading row 121 preferably includes fewer LED's (five for example) than trailing row 119 (which includes an arrangement of LED's as heretofore described), thereby providing the user with easily distinguishable rows in the display during use. The LED rows could also be constituted of different colored LED's in each row (red in leading row 121 and green in trailing row 119 - at least in the strobing inner display 67 thereof) to further distinguish the rows. Leading row 121 elements 123 are preferably positionally offset relative to trailing row 119 elements 69.

Display element group 117, moving a distance the same as "ds" during a stroke, travels at an average velocity the same as the golf club head. A desired average club head velocity at the point of ball impact for an effective golf stroke in a given circumstance (driving, for example) is a known quantity and can be established for a given golfer in training utilizing the apparatus of this invention. Once established, the time delay between leading row 121 and trailing row 119 passage through a given point (ball impact point, for example) can be determined. This quantity (indicative of

the target velocity of the club head) can be programmed at microprocessor 81, and changed programmatically by a trainer or user for differing users, clubs, strokes, or the like. In response, microprocessor 81 operates trailing row 119 as heretofore described, and operates leading row 121 similarly to the inner display elements 69 of trailing row 121 (i.e., activating and deactivating elements 123 in leading row 121 with a predetermined interval period and interval frequency by operation of a separate amplifier/driver for leading row elements 123). However, leading row 121 elements 123 activated interval periods will trail, timewise, the activated interval periods of trailing row 119 elements 69 by the desired time delay quantity.

Thus, if the velocity of the club head is such that the desired time delay is achieved, the two rows of elements will appear as a single row in the persistence display during club use (FIGURE 18A). If the velocity of the club head is slower than the target velocity, the persistence display will so indicate (FIGURE 18B). If the club head velocity exceeds the target velocity the persistence display will appear as shown in FIGURE 18C.

In addition to showing target velocity variations, the leading row/trailing row 121/119 relative positions

can also indicate the angle of the club head face. If display element group 117 is rotated clockwise (indicative of an open club face for a right handed golfer), leading row 121 will appear to be shifted toward the outside of the display (toward the toe of the club) relative to trailing row 119 in the persistence display as shown in FIGURE 18D. If, on the other hand, display element group 117 is rotated counter-clockwise (indicative of a closed club face for a right handed golfer), leading row 121 will appear to be shifted toward the inside of the display (toward the heel of the club) relative to trailing row 119 in the persistence display as shown in FIGURE 18E. Both FIGURES 18D and 18E indicate club head speed at the target velocity. If the target velocity is not achieved in either case, the same persistence display shift with occur, but the rows will not be aligned (as discussed heretofore).

Another embodiment 131 of elongated light emitting display 67 used with apparatus 31 of this invention is shown in FIGURE 19. Embodiment 131 uses a single elongated element as the sole source of light emissions creating the rungs 77 in the persistence display. Embodiment 131 preferably utilizes an elongated optical fiber element (or strand) 133 to replace the plural

elements 69 as shown in FIGURE 5 (though other single source elements could be utilized such as a small bar lamp or the like). Fiber optic element 133 is connected with fiber optic transmitter 135 (including a laser and light amplifier and/or wave guide, for example) which converts the electrical signal from driver 137 to light channeled through element 133 in a conventional manner. In this embodiment, the single source element could be utilized with or without outside display elements 63/65 and with or without user selection input 89 to provide a usable and intuitive persistence display (though simplified in its deployment in some implementations).

As may be appreciated from the foregoing, a golfer utilizing the various apparatus and methods of this invention can perceive open or closed club face orientation, club path through the ball strike, club face impact point with the ball, and both absolute and relative club head velocity. The apparatus relays information to the golfer during each swing and in a very intuitive manner, which allows the golfer to find and correct defects in his or her swing that might never be discovered using conventional methods.